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Influence of Environmental Conditions and Call Playback on Detection of Eastern Forest Owls During Standardized Surveys

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INFLUENCE OF ENVIRONMENTAL CONDITIONS AND CALL PLAYBACK ON DETECTION OF EASTERN FOREST OWLS DURING STANDARDIZED SURVEYS

by

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ABSTRACT

Owls provide ecosystem services and play crucial roles in the environment making them important to monitor and study. However, standardized methods for most species do not exist, and we lack understanding of the effects of many environmental variables and playbacks on detection probability of owls. We performed a multispecies occupancy analysis on owl monitoring data collected from 2004 – 2013 across the state of Maine, to examine the effects of environmental variables, conspecific and heterospecific playback on detection, and general survey protocols for three forest owls: Northern Saw-whet Owl (*Aegolius acadicus*), Barred Owl (*Strix varia*), and Great Horned Owl (*Bubo virginianus*). We found that environmental variables such as cloud cover, precipitation, temperature, time of night, and wind have species-specific results, but noise resulted in decreased detection probability for all species. We did not find support for effects of snow cover or latitude on detection of any species. We also found that conspecific playback increased the detection of that species, and heterospecific playback had variable effects. Specifically, we found that Long-eared and Barred Owl playback increased the detection of Northern Saw-whet Owl, and our results suggest additional heterospecific effects may exist. Our study showed that compared to the Maine Owl Monitoring Program, surveys examining all three of our focal species can increase efficiency and lower disturbance by only broadcasting Long-eared and Barred Owl playbacks during a 10-minute survey. We recommend that future owl surveys take into account species-specific effects of conspecific and heterospecific playback, and use our results when designing survey protocols that include one or more of our focal species.

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INTRODUCTION

Understanding changes in the status and occupancy of owls (Strigiformes) is important because they act as indicators of ecosystem status, and perform essential ecological roles that also benefit humans (Korpimäki 1994, Solonen et al. 2015, Labuschagne et al. 2016). Owls provide crucial ecosystem services through predation of rodent (Mammalia: Rodentia) pests, which results in the reduction of rodent-transmitted diseases that affect wild and domestic animals, as well as humans (Singleton et al. 2010, Labuschagne et al. 2016, Muñoz-Pedreros et al. 2016). For this reason, owls are also a key resource in food security (Muñoz-Pedreros and Gil 2009, Singleton et al. 2010, Labuschagne et al. 2016). Owls may also be vulnerable to climate and land-use change due to disturbances such as logging, urban development, and agriculture (Franklin et al. 2000, Grossman et al. 2008, Schilling et al. 2013, Eslarski and Cintra 2014). Changes in weather and climate, additionally, have been shown to explain most of the temporal variation in survival, reproductive output, and recruitment of at least some owl species (Franklin et al. 2000). Monitoring owls is therefore essential to understanding how drivers of global change will affect owl populations, and as a consequence influence the ecosystem services they provide.

Methods for surveying owls are highly variable among species and locations, but most forest owls are surveyed using nocturnal playback surveys to elicit responses and confirm presence (Johnson et al. 1981, Kissling et al. 2010). The sequence of playback, the type of playback used, and the conditions in which surveys are conducted can greatly alter detection probability. Temporal, climatic, and lunar factors affect owl vocalizations and detection, and broadcasting recorded owl calls (playback) can increase detection, but the effects of playback on non-target species is not well understood (Clark and Anderson 1997, Kissling et al. 2010, Odum and Mennill 2010, Neri et al. 2018). The spatial distribution of conspecifics and heterospecifics affect owl survival, presence, and use, and responses to playback and environmental conditions often are species-specific (Grossman et al. 2008, Odum and Mennill 2010, Neri et al. 2018). For some species, such as the Burrowing Owl (*Athene cunicularia*), substantial literature regarding survey protocols exists (e.g., Conway et al. 2007, Manning 2011). For forest owls, however, widely accepted standard survey protocols only exist for Spotted Owls (*Strix occidentalis*) (Franklin et al. 1996, Lint et al. 1999). Although some owls are known to respond to conspecific playback (McGarigal and Fraser 1985, Odum and Mennill 2010, Neri et al. 2018), we lack understanding of how the detection probability of forest owls changes in response to playback of other species, and under varying environmental conditions.

Although many non-methodological studies have been conducted on eastern forest owls, the effectiveness of owl survey methods is not well studied. Banding stations have provided a successful way to monitor the migration of small forest owls such as Northern Saw-whet Owls (Confer et al. 2014), but this method is not appropriate for breeding owls. Although the effects of environmental conditions on some forest owl species have been studied (Kissling et al. 2010), this research has not been conducted in eastern North America. It is also unclear how most eastern forest owls respond to playback of heterospecifics, except Great Horned Owl, which has been shown to respond positively to calls of other species (Bosakowski and Smith 1998). In Maine, where 90% of the landscape is covered with forests (Acheson and McCloskey 2008), the three most common and widely detected species are the Northern Saw-whet (*Aegolius acadicus*), Barred (*Strix varia*), and Great Horned Owl (*Bubo virginianus*). Survey methods, heterospecific playback, and environmental effects specific to this region have yet to be evaluated for these common species to date.

In this study our goal was to evaluate the effect of survey protocols, environmental conditions, and playbacks on detection of our three focal species: Northern Saw-whet Owl, Barred Owl, and Great Horned Owl. To accomplish this, we analyzed owl survey data collected during 2004 – 2013 as part of the Maine Owl Monitoring Program (MOMP), a 10-year citizen-science project conducted to better understand the status and distribution of owls throughout the state of Maine. We used multi-species occupancy models to examine how detection probability of each species varied according to survey-level environmental conditions as well as in response to playback calls of four owl species (the three focal species plus Long-eared Owl; *Asio otus*). Our specific objectives were to: (i) evaluate MOMP survey methods and effectiveness of these surveys at detecting owls, (ii) determine the effects of environmental conditions on detection, (iii) examine the effects of conspecific and heterospecific playback on detection, and (iv) make recommendations to improve survey protocols for each of the focal species. We hypothesized that playback of a species would increase the probability of detecting that species (Francis and Bradstreet 1997). Additionally, we predicted that Northern Saw-whet and Long-eared Owl playback would increase the probability of detecting Barred and Great Horned Owl due to competition for food (Marti et al. 1993). We predicted detection of all species would be lower during environmental conditions where either sounds were muffled, or when owl activity was reduced (Kissling et al. 2010). However, we also predicted the strength of these effects would be species-specific (Conway et al. 2007, Braga and Motta-Junior 2009).

METHODS

Maine Owl Monitoring Program

MOMP consisted of a pilot study during 2002 and 2003 to evaluate methods and study design for a primary study conducted from 2004 to 2013. The main goals of the program were to (1) examine owl abundance and distribution in Maine, (2) evaluate survey methods and monitoring effectiveness, and (3) build a long-term citizen-science project through a network of skilled volunteers (Hodgman & Gallo 2004).

Survey routes were established using the Maine DeLorme Atlas (Olathe, KA) grid system to delineate survey blocks that were further divided into four equal quadrants. Within each quadrant, two survey routes were established, however not all routes were sampled equally or sequentially across the study years. Participants were asked to sample their assigned route once during a 6.5-week survey period that started on the first Friday of March each year. All surveys were conducted between 2400 – 0500 hours.

Along each route, participants established ten survey locations that were separated by a minimum distance of 1 mile. During each survey, participants recorded start time, and quantified temperature, cloud cover, snow cover, wind, noise, and precipitation. Temperature was estimated using handheld thermometers or from regional weather records. Cloud cover represented the percentage of the sky covered by clouds, estimated to the nearest 10%. Snow cover was recorded along a categorical gradient where 1 = no snow cover, 2 = patchy or partial snow cover, and 3 = complete ground cover. Wind speed was approximated following the Beaufort scale from 0 – 5 where 0 = < 1 mph, 1 = 1 – 3 mph, 2 = 4 – 7 mph, 3 = 8 – 12 mph, 4 = 13 – 18 mph, and 5 = 19 –

24 mph winds. Noise was quantified on a scale from 1 – 4, where 1 = relatively quiet, 2 = moderate noise but not affecting ability to hear owls, 3 = loud noise that may affect detection of owls, and 4 = excessive loud noise that probably affects detection of owls. Precipitation was scored categorically from 0 – 6 where 0 = none, 1 = drizzle, 2 = light rain, 3 = steady rain, 4 = sleet, 5 = flurries, and 6 = snow. Surveys were not conducted in high winds (> 3 on the Beaufort scale) or during precipitation > 1 on the scale.

Surveys began with three minutes of passive listening, followed by a playback and a 1-minute 40-second listening period. At the start of the 5th minute of the survey, a second playback of a different species was used, followed by a 5-minute 40-second listening period. At minute 11 a final playback of a third species was broadcast, followed by another 1-minute 40-second listening period, the end of which marked the completion of the survey. All playbacks were broadcast for 20-seconds. During 2004 – 2006, Northern Saw-whet, Barred and Great Horned Owl calls were played, in that order. From 2007 – 2013, the Northern Saw-whet Owl playback was replaced with a Long-eared Owl playback. During each survey, participants recorded all owls heard or seen in each of the 16 sampling intervals, which consisted of 60-second listening intervals (n=10), 20-second playback intervals (n=3), and 40-second listening intervals (n=3; the remainder of the minute post-playback). During initial years participants used cassette tapes with recordings of the calls of the focal species for broadcasting playbacks, while during later years, the option to use a 13-minute recording that was structured to play different owl playbacks at the designed times was offered. Participants chose to either use this new method, or continue using the cassette tapes.

Modeling Procedures

We constructed species-specific detection histories using owl detections during each sampling interval (i.e. 20-, 40-, or 60-second period) as temporally-repeated observations, and examined the effects of environmental covariates and playback on species detection probabilities (p) using a multispecies occupancy framework (Rota et al. 2016) in program MARK (White and Burnham 1999). We only examined detection probability of Northern Saw-whet, Barred, and Great Horned Owl; all other species recorded during MOMP surveys had a sample size of < 100 detections, and were therefore not considered. We modeled all effects independently (i.e. a unique Beta coefficient) for each species because our goals were to understand species-specific changes in detection in response to environmental and playback effects. Our objectives were strictly related to detection probability, so we used a general structure for the occupancy component of the model that allowed for year-specific occupancy for each of the three focal species (i.e. a year*species interaction). This occupancy structure was held constant across all models, and occupancy parameters reached convergence in all analyses. All covariates were z-standardized (mean = 0.0, SD = 1.0). We used Akaike information criterion adjusted for small sample size (AIC_c) to rank the models following a criterion of ΔAICc < 2.0 for models to be competitive.

We began model selection for the detection probability component of the analysis by running models with additive or interactive effects of species, ordinal date, and year, and tested quadratic effects of ordinal date. From this model set, we selected the best-performing model and used this as a base structure upon which we built all further models. We then tested individual models with additive effects of the following eight covariates on detection of each species: time of survey expressed as time since midnight, temperature, cloud cover, snow cover, wind, noise, precipitation, and latitude. We combined covariate effects that performed better than the base model into a singular comprehensive model, from which all inference was made. However, we conducted a correlation matrix analysis between all covariates in program R (version 3.4.2), and found that no two covariates were correlated (r > 0.5). We used the Beta coefficients (β) and their 95% confidence intervals to further evaluate covariate support (95% CI does not overlap zero) and relative differences in effects among species (differences in species-specific β for each supported variable).

To determine the effects of the playback on detection of the three species of owl, we used the best model from our base model selection (combined species, date and year effects) and created individual models with effects for each of the four species' playbacks, applied independently (i.e. unique β coefficients) to detection probability for each of the three focal species. We examined the effect of each playback on each species where we modeled a unique detection probability for the 20-second period of playback and each subsequent sampling interval until the next species' playback began. For Great Horned Owl, the effect of playback was modeled to include the 20-second playback and the remaining sampling intervals until the end of the survey. Effects of Northern Saw-whet Owl and Long-eared Owl playback were limited to the years in which they were played (NSWO = 2004 – 2006; LEOW = 2007 – 2013). Although detections of Long-eared Owl were too infrequent to analyze, we still included the effects of Long-eared Owl playback on our three focal species because it was played for seven years of the surveys, and it has been shown that heterospecific playback can effect detection of other owl species (Bosakowski and Smith 1998). Based on preliminary results, we eventually combined all four playback structures into one comprehensive model, and made further inferences and interpretations from this combined model that also included an effect of the playback interval on the detection of all species. We also ran a post-hoc model to specifically examine the effects of Barred Owl playback on Northern Saw-whet Owl detection, where we modeled Barred Owl playback effects only during the years in which Long-eared Owl was broadcast (2007 – 2013). This allowed us to evaluate whether the effect of Barred Owl playback on Northern Saw-whet Owl detection was still supported without the bias of Northern Saw-whet Owl playback.

In all analyses, we interpreted only detection estimates and did not draw inference from occupancy parameters, except to ensure that estimates reached convergence. For this reason, conforming to all assumptions of occupancy models was not required. For example, survey routes were not evenly sampled through all years of the survey, and were not independent given that the same breeding pair could return each year. However, our objectives do not require us to meet these assumptions as we were only interested in species-specific effects on detection.

To examine how effective surveys were at detecting species presence at a given survey location and determine the most efficient and effective survey structure for each species singly as well as combined, we used estimates of interval-specific detection probabilities from our best-supported model to calculate $p*$ as

$$p* = 1 - \left(\prod_{1:n}(1 - p)\right)$$

which estimates the probability that each species was detected at least once during a survey of *n* intervals, where p is the probability of detection during a single sampling interval (*i*). We used real parameter estimates (*p*) from the most competitive model of our playback model selection, and calculated $p*$ under a variety of scenarios to explore how potential differences in playback structure and survey length could affect detection of each species during the survey. We used values of p from years that were closest to the mean value for each species, and assumed mean values for all environmental covariates.

We first calculated $p*$ for each successive survey length (e.g. 1 interval, 2 intervals, etc.) under the existing protocol for each of the three focal species, and we repeated this for both when Northern Saw-whet Owl was played first and when Long-eared Owl was played first. We then explored hypothetical alternative survey structures where we assumed only two playbacks were broadcast (i.e., either Northern Saw-whet or Long-eared plus Barred Owl), and where we assumed only one playback was broadcast (Northern Saw-whet or Long-eared only) during the survey (Table 1). We also explored a hypothetical survey structure consisting of only passive listening, which we compared all alternative playback structures to. We report change in predicted detection probability by increasing survey duration, and evaluated differences in relative ability to detect each species among survey structure based on the number of intervals required for a species' detection probability to reach values of both > 0.50 and > 0.95. In cases where two survey structures achieved the same $p*$ on the same minute, we considered the survey structure with the fewest number of playbacks to be more ideal because fewer playbacks could limit disturbance and chance of human error.

RESULTS

From 2004 – 2013, MOMP participants completed 5280 stop-level surveys across 110 different routes throughout the state. At least one of the three focal species was detected on 32% of surveys (1705 surveys). Barred Owls were most frequently detected species (23% of surveys), followed by Northern Saw-Whet Owl (8% of surveys), and Great Horned Owl (6% of surveys).

We found support for species-specific effects of year as well as species-specific effects of date (quadratic) on detection (Table 2). We found no support for Northern Saw-whet and Barred Owl detection changing with date of the survey (β_{NSWO} = 0.050; 95% CI = -0.158 to 0.058; β_{BADO} = 0.071; 95% CI = -0.006 to 0.147), but detection probability of Great Horned Owl was greatest at the start of the survey season (e.g., early March), and decreased thereafter (β_{GHOW} = -0.227; 95% CI = -0.375 to -0.079).

Environmental Covariates

Models that included latitude and snow cover were not supported (Table 3). All other covariates performed better than the base model, and were combined into a single comprehensive model (Table 3). We did not find support that time of night affected detection probability of Northern Saw-whet Owl (β_{NSWO} = -0.057; 95% CI = -0.118 to 0.004) or Barred Owl (β_{BADO} = -0.036; 95% CI = -0.076 to 0.004), but detection of Great Horned Owl increased as time since midnight increased (β_{GHOW} = 0.092; 95% CI = 0.005 to 0.178). Cloud cover increased detection of Barred Owl slightly (β_{BADO} = 0.045; 95% CI = 0.005 to 0.085), but we found no support for effects on Northern Saw-whet Owl (β_{NSWO} = 0.030; 95% CI = -0.034 to 0.094) or Great Horned Owl (β_{GHOW} = -0.052; 95% CI = -0.127 to 0.023). There was no support for an effect of temperature on detection of Northern Saw-whet Owl (β_{NSWO} = 0.018; 95% CI = -0.040 to 0.077) or Barred Owl (β_{BADO} = 0.045; 95% CI = -0.001 to 0.090), but as temperature increased, detection of Great Horned Owl decreased (β_{GHOW} = -0.124; 95% CI = -0.227 to -0.022). Precipitation negatively affected the detection Northern Saw-whet Owl (β_{NSWO} = -0.091; 95% CI = -0.170 to -0.013) and Barred Owl (β_{BADO} = -0.043; 95% CI = -0.079 to -0.007), but there was no support for an effect on Great Horned Owl (β_{GHOW} = -0.013; 95% CI = -0.107 to 0.081). Higher wind speeds decreased detection of Northern Saw-whet Owl (β_{NSWO} = -0.185; 95% CI = -0.253 to -0.116) and Great Horned Owl (β_{GHOW} = -0.142; 95% CI = -0.218 to -0.066), but effects on Barred Owl detection had no support (β_{BADO} = -0.039; 95% CI = -0.070 to 0.006). We found that higher noise levels decreased the detection of all three species (β_{NSWO} = -0.100; 95% CI = -0.154 to -0.046; β_{BADO} = -0.052; 95% CI = -0.089 to -0.015; β_{GHOW} = -0.138; 95% CI = -0.210 to -0.066).

Effects of Playback

All models that included the effect of a playback performed better than the base model, so all playback effects were combined into a single model structure, which was best supported (Table 4). From this model, we found that detection of owls was substantially decreased in general during the 20-second playback periods compared to non-playback periods of the survey (β_{pb} = -2.031; 95% CI = -2.150 to -1.913). Following the completion of playback, each of the four species' calls produced varying effects on subsequent detection that differed among species. Northern Saw-whet Owl playback increased detection of Northern Saw-whet Owl (β_{NSWO} = 0.793; 95% CI = 0.571 to 1.015), but we found no support for an effect on detection of Barred Owl (β_{BADO} = -0.005; 95% CI = -0.196 to 0.187) or Great Horned Owl (β_{GHOW} = 0.299; 95% CI = -0.003 to 0.602) during the 3-minute period following playback. Long-eared Owl playback did not have support for an effect on detection of Barred Owl (β_{BADO} = 0.076; 95% CI = -0.071 to 0.223) or Great Horned Owl (β_{GHOW} = 0.198; 95% CI = -0.056 to 0.453), but increased detection of Northern Saw-whet Owl (β_{NSWO} = 0.540; 95% CI = 0.307 to 0.773). We found that Barred Owl playback increased the detection of all three species, but was strongest for Barred Owl (β_{BADO} = 0.740; 95% CI = 0.644 to 0.836), followed by Northern Saw-whet Owl (β_{NSWO} = 0.691; 95% CI = 0.544 to 0.838), and finally Great Horned Owl (β_{GHOW} = 0.392; 95% CI = 0.221 to 0.563). This positive effect of Barred Owl playback on Northern Saw-whet Owl detection was also supported in our post-hoc model that examined this effect exclusively in years when Northern Saw-whet Owl playback was not broadcast (β_{NSWO} = 0.367; 95% CI = 0.213 to 0.520). Great Horned Owl playback also increased detection of all three species, but was strongest for Great Horned Owl (β_{GHOW} = 0.508; 95% CI = 0.299 to 0.716), followed by Northern Saw-whet Owl (β_{NSWO} = 0.370; 95% CI = 0.186 to 0.554), and finally Barred Owl (β_{BADO} = 0.327; 95% CI = 0.206 to 0.448).

Survey Duration and Structure

From our $p*$ analysis, we determined that the surveys conducted under the MOMP protocol using playbacks of Northern Saw-whet, Barred, and Great Horned Owls had a high likelihood of detecting each owl species at least once during the survey, given that it was present at a site ($p*_{\text{NSWO}}$ = 0.997; $p*_{\text{BADO}}$ = 0.981; $p*_{\text{GHOW}}$ = 0.996). Under this survey structure, Northern Saw-whet Owl detection reached $p* > 0.95$ by minute 7, Barred Owl detection reached $p* > 0.95$ by minute 11, and Great Horned Owl detection reached $p* > 0.95$ by minute 8 (Table 6). Survey structures that replaced Northern Saw-whet Owl with Long-eared Owl also had a high probability of detection for all three focal species by the end of the survey, given presence

($p*_{NSWO}$ = 0.996; $p*_{BADO}$ = 0.983; $p*_{GHOW}$ = 0.996). For this survey structure, Northern Saw-whet Owl detection reached $p* > 0.95$ by minute 8, Barred Owl detection reached $p* > 0.95$ by minute 10, and Great Horned Owl detection reached $p* > 0.95$ by minute 8 (Table 6). For both of these survey structures, the detection of all three species reached $p* > 0.95$ before the Great Horned Owl playback was broadcast.

When we considered hypothetical scenarios where only two-species playbacks were assumed, we found that broadcasting Northern Saw-whet and Barred Owl playback, but not Great Horned Owl, did not alter ability to detect any of the three focal species (Table 6). Similarly, we found that broadcasting Long-eared and Barred Owl playback, but not Great Horned Owl, again did not alter ability to detect any species (Table 6). We also tested single-playback scenarios, and found that only broadcasting Northern Saw-whet Owl playback did not change the detection of Northern Saw-whet Owl, but showed that even a 13-minute survey duration would not reach $p* > 0.95$ for Barred Owl (Table 6). This survey structure also required a longer survey duration for Great Horned Owl; $p* > 0.95$ was not reached until minute 10 (Table 6). Only broadcasting Long-eared Owl playback increased the survey duration needed to reach a detection of $p* > 0.95$ for Northern Saw-whet Owl (8 minutes), Barred Owl (10 minutes), and Great Horned Owl (8 minutes; Table 6).

The survey structure that was most efficient, effective, and required the fewest playbacks for Northern Saw-whet Owl was only broadcasting Northern Saw-whet Owl playback (Figure 2). For Barred Owl, the optimal survey structure was broadcasting Long-eared Owl and then Barred Owl playback (Figure 3). For Great Horned Owl, the optimal survey structure can be either using Northern Saw-whet and Barred Owl playback, or Long-eared and Barred Owl playback structure

(Figure 2 & 3). The optimal structure for a survey that aims to detect all three species at once was the Long-eared Owl followed by Barred Owl playback (Figure 3).

DISCUSSION

We found that conspecific and heterospecific playback affected detection of our focal species, where conspecific playback consistently increased detection of those species. This increased detection of conspecifics has been widely demonstrated in avian literature, where increased detection in response to conspecific playback has been well documented in owls, marsh birds, and many families of passerines (Bosakowski and Smith 1998, Hannah 2009, Conway and Gibbs 2005, Kissling et al. 2010, Grinde et al. 2018). Our study also suggests that playback of heterospecifics can affect detection of a species, but these effects are species-specific. The effect of heterospecific playback has been examined across a range of avian taxa, and found to have varying effects depending upon the relationship the two species exhibit. Heterospecific playback of a predator may increase abundance and detection of mobbing passerines, but for families such as blackbirds (Icteridae) detection may decrease as they hide to escape predation (Grinde et al. 2018). Also, for difficult to detect species (i.e. secretive marsh birds) heterospecific playback has been shown to increase detection (Conway and Nadeau 2010). For forest owls, Great Horned Owl detection has been shown to increase in response to heterospecific playback (Bosakowski and Smith 1998). Our study showed that detection of Northern Saw-whet Owl increased in response to Long-eared Owl playback and Barred Owl playback (Table 5). Our hypothetical survey structures show that compared to a survey of passive listening and no playback, an addition of any of the four species' playback we analyzed decreased the time required to achieve a high detection probability. Future surveys need to understand and account for the effects of playback of conspecifics and heterospecifics on detection of focal species.

Our study determined that owl surveys for Northern Saw-whet, Barred, and Great Horned Owls can use fewer playbacks and increase efficiency relative to the MOMP study design. We predicted that optimal survey protocols to reach > 0.95 detection probability most efficiently for each of our focal species used fewer playbacks over a shorter duration than the MOMP surveys, which broadcast three playbacks over 13 minutes (Table 6). If the goal of a study is to examine all three of these focal species at once, we predict that the optimal survey protocol is broadcasting Long-eared Owl followed by Barred Owl playback during a 10-minute survey (Figure 3). The exact duration required for a survey depends on the desired detection probability of a given study; we chose a rather high probability of detection ($p^* > 0.95$) as a threshold for the purpose of comparison, but our results scale to lower detection probability benchmarks (Figure 3). We also provide a table of detection probabilities for each successive minute of the survey length (see appendix: Table A2), which gives the full range of p^* values for all survey lengths and playback sequences. Future research can use these values in designing owl surveys based on their minimum detection probability targets.

We acknowledge several limitations to our study that are important to consider when interpreting our results. First, when the field protocols were designed the primary goal was to evaluate owl abundance and distribution in Maine, and not to study survey design per se. As such, the order and duration of playbacks were not varied among surveys in an experimental design, which restricts some of the inference we can make from some aspects of the playback effects on owl detection. Because the order of calls were fixed, Barred Owl playback was always broadcast after either Northern Saw-whet or Long-eared Owl, and Great Horned Owl was always played after Barred Owl and either Northern Saw-whet or Long eared Owl. This may partially explain the positive effects of Barred and Great Horned Owl playback on our three focal species as the positive effects from previous conspecific calls could have carried over into the intervals following Barred and Great Horned Owl playbacks. Alternatively, this could be due to these species responding to the playback of heterospecifics, as has been seen in Great Horned Owl (Bosakowski and Smith 1998). However, our post-hoc models show the positive effect of Barred Owl playback on Northern Saw-whet Owl detection persisted even when Northern Saw-whet calls were not used during 2007-2013, suggesting true heterospecific effects of Barred Owl playback on detection of Northern Saw-whet. Long-eared and Northern Saw-whet Owl playback effects are robust to any carry-over effects because they were always played first. Since Great Horned Owl playback was always played last there is some uncertainty with respect to heterospecific effects, but even during the full MOMP surveys we see that all species reach > 0.95 detection probability before Great Horned Owl playback is broadcast (Table 6), which is not true of any other species.

Our study also showed that detection probability can be affected by environmental conditions, and responses are often species-specific. We found that temperature, precipitation, and wind had strong effects on detection of forest owls, as did the ambient noise levels from anthropogenic and natural sources. In contrast, latitude and snow cover, which were not supported models, may not impact detection of eastern forest owls. Only Great Horned Owl detection decreased with higher temperatures, which could be due to these owls becoming more difficult to detect during the later dates in the survey season considering their breeding season is earlier and more restricted compared to the other focal species (Artuso et al. 2013). MOMP survey protocols may have decreased our ability to detect strong effects in some environmental covariates because they were not conducted in extreme conditions. Specifically, surveys were never conducted in strong winds (> 12 mph) or in more than light precipitation (> 1 on the precipitation scale), but even the difference between light and no precipitation showed decreased detection of Northern Saw-whet and Barred Owls. This could be due to the noise created by precipitation and deterrence of owls calling, and aligns with studies in Alaska that found the same effect of precipitation on detection of these two species (Kissling et al. 2010). As hypothesized, detection probability of all three focal species decreased when ambient noise from both natural (i.e. streams) and anthropogenic sources was high. Therefore, recording and correcting for noise is critical, and cannot be controlled through survey protocol or design. These environmental conditions play major roles in the detection of forest owls and are essential to assess and measure in owl surveys.

The time of year in which surveys were conducted affected detection probability of Great Horned Owl. Specifically, we found support for decreased detection of Great Horned Owl as the date approached late April. Similar to the effects of temperature, this decreased detection is likely due to the early and restricted breeding season of this species, which results in earlier termination of mating calls (Johnsgard 1988, Artuso et al. 2013). Northern Saw-whet Owl detection did not change throughout the surveying period. We also did not find support for Barred Owl detection changing throughout the study duration, but Kissling et al. (2010) showed that Barred Owl detection decreased closer to summer. MOMP surveys were always completed by late April, which may mean that we did not sample long enough to detect this effect. These findings should be taken into consideration when designing surveying periods for eastern forest owls as species may differ in the time of year during which detection probability is highest. Based on our results in Maine, the 6.5-week survey period starting on the first Friday of March is adequate for Saw-whet and Barred Owl, but Great Horned Owl may benefit from an earlier survey period.

For future owl monitoring projects or studies located in the northeastern US or southeastern Canada that include any of our three focal species, we recommend using our predicted optimal survey structures discussed above, and using Table A2 (see appendix) to quantify the required survey duration according to a given study's desired detection probability. Researchers should also organize dates of sampling to take into account the biology of each species in the study. For example, for Great Horned Owl surveys may need to be conducted earlier than March when temperatures are colder and before nesting has begun (Johnsgard 1988, Artuso et al. 2013). Surveys should not be conducted in winds ≥ 3 on the Beaufort scale (Grossman et al. 2008), or during precipitation scoring > 1 (i.e. drizzle), and should aim to quantify noise levels, including the number cars and planes that pass (as seen in Gill et al. 2015, Iglesias-Merchan et al. 2015). We suggest that these survey protocols and effects of environmental conditions be taken into account in other locations, but recommend a preliminary study to determine the most robust survey methods in a particular system (Kissling et al. 2010).

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APPENDIX

TABLE 1. Six different playback scenarios for which we calculated *p** for each of the three focal owl species. Data were collected from survey routes distributed throughout Maine, USA, from 2004 – 2013.

Model Structure	1st Playback[a]	2nd Playback[a]	3rd Playback[a]
3-playbacks	Saw-whet	Barred	Great Horned
	Long-eared	Barred	Great Horned
2-playbacks	Saw-whet	Barred	NA
	Long-eared	Barred	NA
1-playbacks	Saw-whet	NA	NA
	Long-eared	NA	NA

[a] "Saw-whet", "Long-eared", "Barred", and "Great Horned" represent the playback of Northern Saw-whet, Long-eared, Barred, and Great Horned Owls respectively.

TABLE 2. Performance of base multispecies detection models to determine best temporal and species model structure for use in further analysis of owl roadside survey data. Models were run using a multispecies occupancy analysis in Program MARK, and data were collected from survey routes distributed throughout Maine, USA, from 2004 – 2013.

Model[a]	**ΔAIC_c**[b]	**w_i**[c]	**k**[d]	**Deviance**
(Spp * Year * Date^2)	0.00	1	70	46373.62
(Spp * Year)	68.13	0	64	46454.05
(Spp * Date^2)	134.05	0	43	46562.79
(Spp + Year)	134.46	0	46	46557.10
(Spp + Date^2)	149.78	0	39	46586.64
(Spp * Date)	170.57	0	40	46605.41
(Spp + Date)	174.27	0	38	46613.16
(Spp)	192.91	0	37	46633.83
(Null)	386.96	0	35	46831.94

[a] All models assume interaction between year and species effects on the occupancy term. “Spp” represents that detection was modeled differently between species (i.e., Northern Saw-whet, Barred, and Great Horned Owl). “Date” represents the ordinal date of the observation, and “Year” represents an effect of varying detection among years. We denote a quadratic relationship with a square notation (^{2}).
[b] The difference in Akaike’s Information Criterion between the top ranked and focal model.
[c] The relative likelihood of a model (i.e., Akaike weights).
[d] The number of estimated parameters in a given model.

TABLE 3. Performance of multispecies detection models to determine effects of covariates on Great Horned, Barred, and Northern Saw-whet Owl detection. Models were run using a multispecies occupancy analysis in Program MARK, and data were collected from survey routes distributed throughout Maine, USA, from 2004 – 2013.

Model[a]	**ΔAIC_c**[b]	w_i[c]	k[d]	**Deviance**
(Precip + Time + Cloud + Temp + Noise + Wind)	0.00	1	88	46230.22
(Wind)	46.33	0	73	46307.44
(Noise)	58.17	0	73	46319.28
(Temp)	93.44	0	73	46354.54
(Cloud)	96.24	0	73	46357.35
(Time)	102.53	0	73	46363.64
(Precip)	104.55	0	73	46365.66
(Base)	106.36	0	70	46373.62
(Lat)	108.24	0	73	46369.34
(Snow)	110.14	0	73	46371.25

[a] All models assume interaction between year and species effects on the occupancy term. "Base" represents the best model from our base model selection (Table 2). All models include the "Base" structure with added covariate effects. Model names represent covariates applied to the model: Cloud = cloud cover, Lat = latitude, Noise = level of noise, Precip = precipitation, Snow = snow cover, Time = time of survey expressed as time since midnight, Temp = temperature, and Wind = wind speed.
[b] The difference in Akaike's Information Criterion between the top ranked and focal model.
[c] The relative likelihood of a model (i.e., Akaike weights).
[d] The number of estimated parameters in a given model.

TABLE 4. Performance of multispecies detection models to determine effects of broadcasting playback on Great Horned, Barred, and Northern Saw-whet Owl detection probability. Models were run using a multispecies occupancy analysis in Program MARK, and data were collected from survey routes distributed throughout Maine, USA, from 2004 – 2013.

Model[a]	**ΔAIC_c**[b]	w_i[c]	k[d]	**Deviance**
(Saw-whet + Long-eared + Barred + Great Horned)	0.00	1	83	44024.26
(Barred)	93.05	0	74	44135.83
(Barred 2007 – 2013 only)	260.78	0	74	44303.55
(Long-eared)	408.78	0	74	44451.55
(Saw-whet)	410.39	0	74	44453.16
(Great Horned)	436.35	0	74	44479.13
(Base)	2322.64	0	70	46373.62

[a] All models assume interaction between year and species effects on the occupancy term. “Base” represents best model from our base model selection (Table 2). All models include the “Base” structure with added playback effects. “Saw-whet”, “Long-eared”, “Barred”, and “Great Horned” correspond to the effect of a playback of Northern Saw-whet, Long-eared, Barred, and Great Horned Owls respectively.
[b] The difference in Akaike’s Information Criterion between the top ranked and focal model.
[c] The relative likelihood of a model (i.e., Akaike weights).
[d] The number of estimated parameters in a given model.

TABLE 5. Beta estimates (β) of detection and standard error (SE) from a multispecies occupancy analysis in Program MARK for detection of Northern Saw-whet, Barred, and Great Horned Owls in response to Northern Saw-whet, Long-eared, Barred, and Great Horned Owl playback. Data were collected from survey routes distributed throughout Maine, USA, from 2004 – 2013.

Playback Type	Species	$\boldsymbol{\beta}$	SE[a]
Saw-whet	Saw-whet	0.7933	0.1132*
	Barred	-0.0046	0.0975
	Great Horned	0.2992	0.1543
Long-eared	Saw-whet	0.5401	0.1188*
	Barred	0.0758	0.0749
	Great Horned	0.1985	0.1299
Barred	Saw-whet	0.6911	0.0751*
	Barred	0.7398	0.0488*
	Great Horned	0.3921	0.0871*
Great Horned	Saw-whet	0.3703	0.0939*
	Barred	0.3270	0.0619*
	Great Horned	0.5075	0.1062*

[a] Asterisks represent an estimate with 95% CI that do not overlap zero.

TABLE 6. Minutes of survey at which p^* values exceeded 0.50 and 0.95 for Northern Saw-whet, Barred, and Great Horned Owls across hypothetical survey structures, calculated using real estimates from a multispecies occupancy analysis in Program MARK. Data were collected from survey routes distributed throughout Maine, USA, from 2004 – 2013.

Survey Structure	Species	Min of Survey $p^* > 0.50$	Min of Survey $p^* > 0.95$
Saw-whet + Barred + Great Horned	Saw-whet	3	7
	Barred	5	11
	Great Horned	3	8
Long-eared + Barred + Great Horned	Saw-whet	3	8
	Barred	5	10
	Great Horned	3	8
Saw-whet + Barred	Saw-whet	3	7
	Barred	5	11
	Great Horned	3	8
Long-eared + Barred	Saw-whet	3	8
	Barred	5	10
	Great Horned	3	8
Saw-whet	Saw-whet	3	7
	Barred	5	NA
	Great Horned	3	10
Long-eared	Saw-whet	3	9
	Barred	5	13
	Great Horned	3	9
Barred	Saw-whet	3	8
	Barred	4	10
	Great Horned	3	8
No playback	Saw-whet	3	11
	Barred	4	NA
	Great Horned	3	11

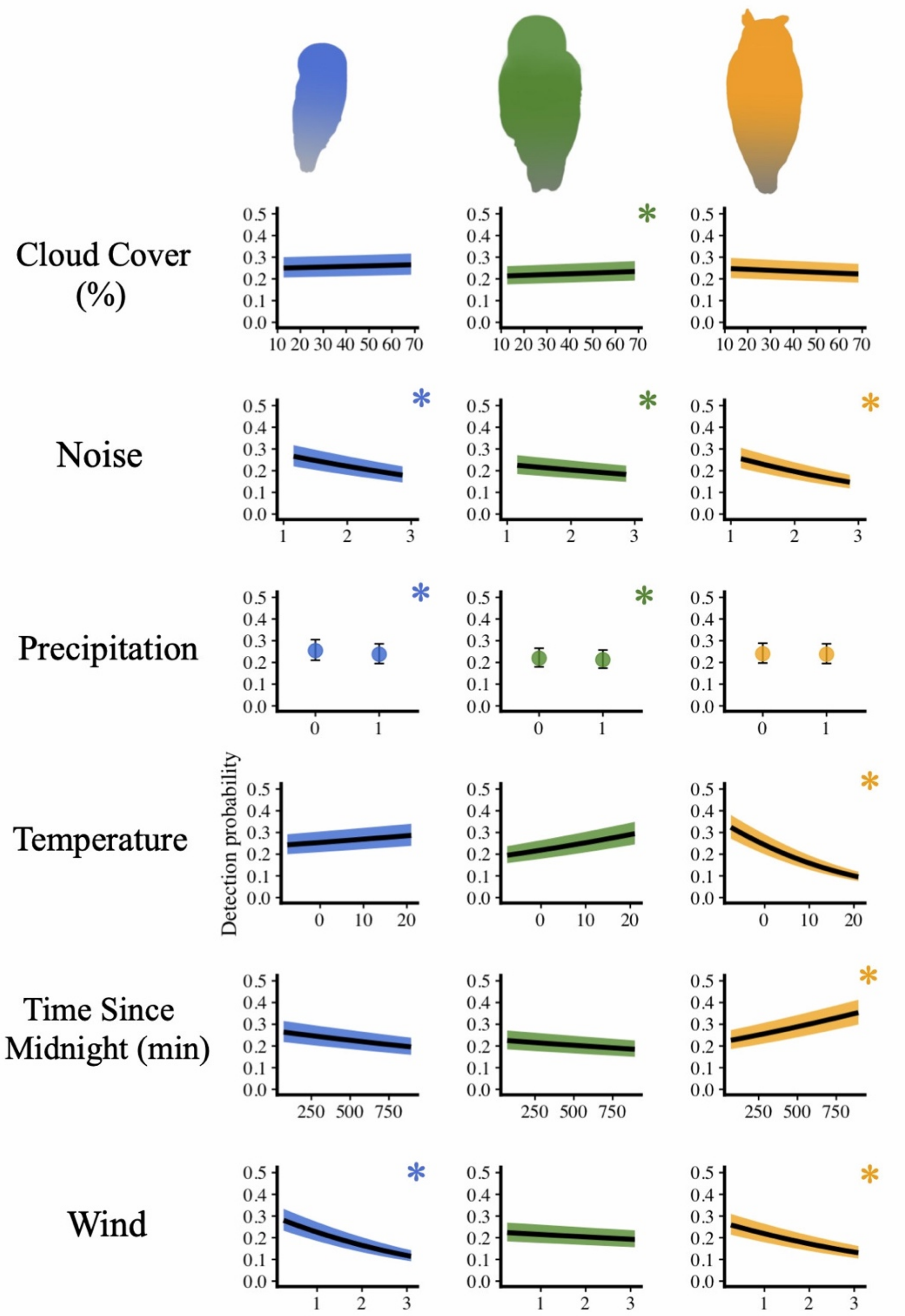

FIGURE 1. Detection probability and 95% confidence intervals for Northern Saw-whet, Barred and Great Horned Owl responses to six environmental covariates. Each column of the matrix represents one of the focal species: Northern Saw-whet, Barred, and Great Horned Owl from left to right. An asterisk represents a 95% CI of the β coefficient that did not overlap zero. Data were

collected from survey routes distributed throughout Maine, USA, from 2004 – 2013, and analyzed using a multispecies occupancy analysis in Program MARK.

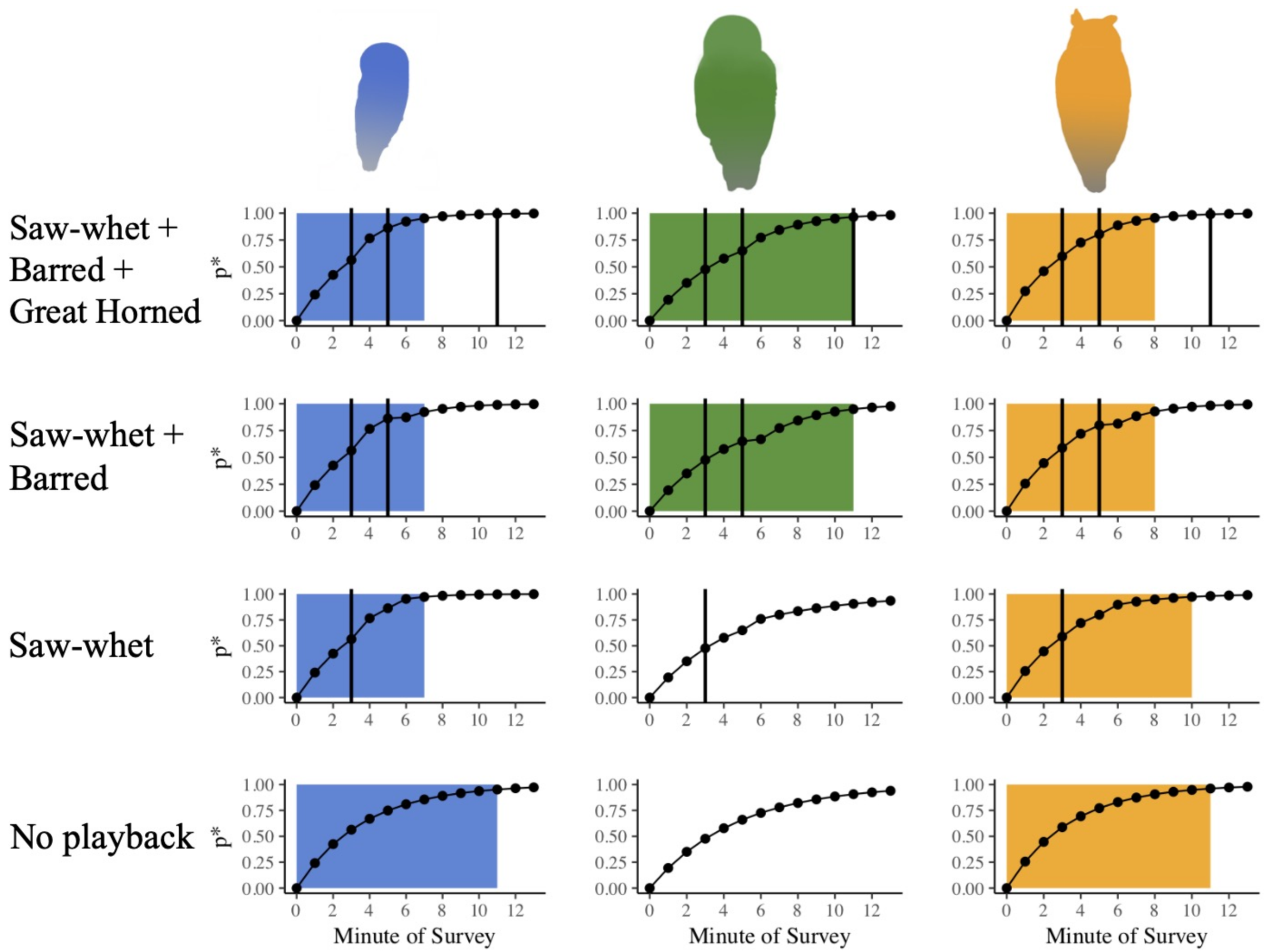

FIGURE 2. Species-specific $p*$ (the estimated probability that each species was detected at least once during a survey of 13 intervals) for three hypothetical scenarios beginning with Northern Saw-whet Owl playback and a scenario with no playback for comparison. Each row of the graph matrix represents the effect of the playback sequence listed on the far left. Each column of the matrix represents one of the focal species: Northern Saw-whet, Barred, and Great Horned Owl from left to right. Vertical black lines represent the point in time when a playback was broadcast, and the colored blocks denote the period of time where the cumulative detection probability was < 0.95. Colored blocks are absent when the period of time where the cumulative detection probability was < 0.95 required more than 13 minutes. Data were collected from survey routes distributed throughout Maine, USA, from 2004 – 2013, and analyzed using a multispecies occupancy analysis in Program MARK.

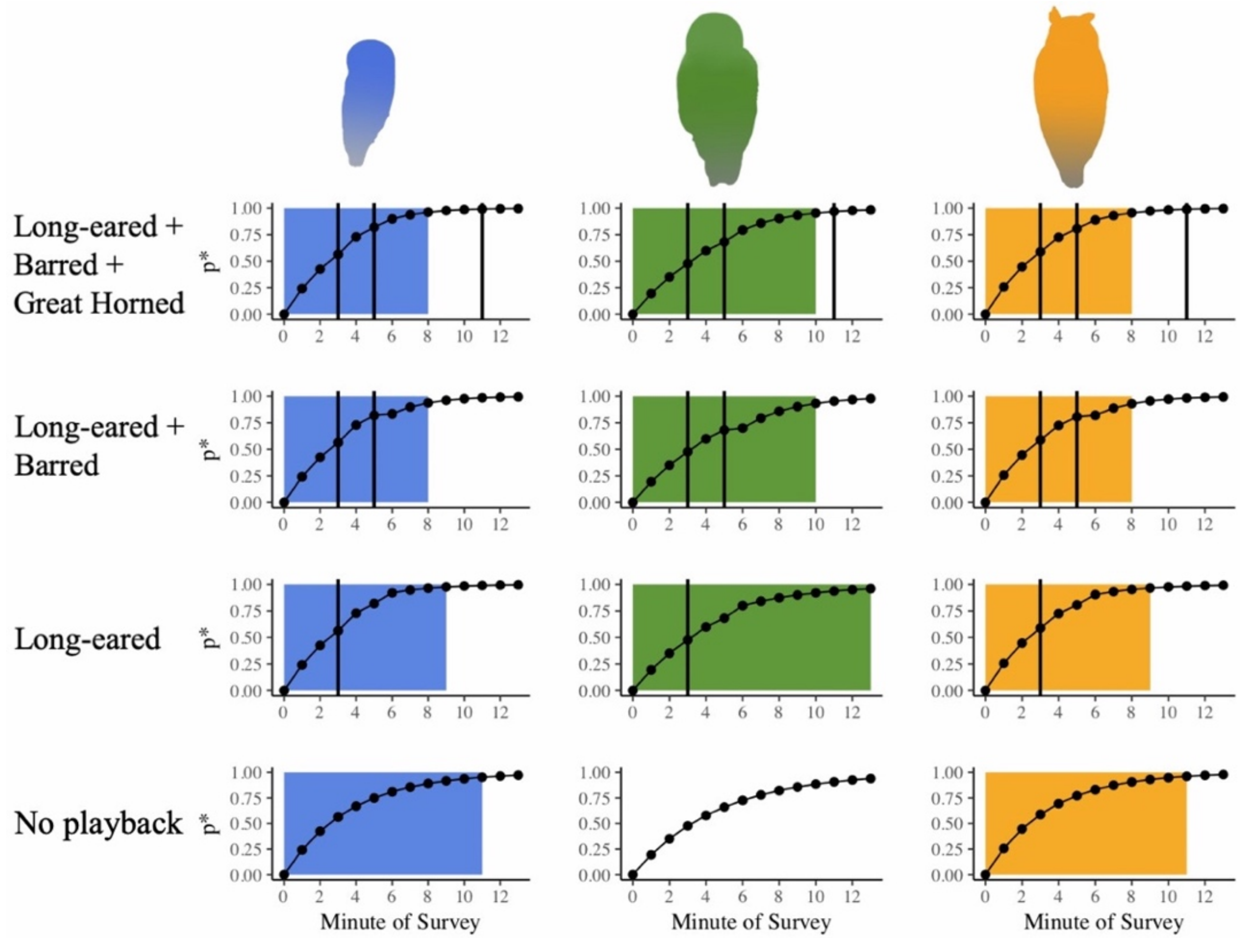

FIGURE 3. Species-specific $p*$ (the estimated probability that each species was detected at least once during a survey of 13 intervals) for three hypothetical scenarios beginning with Long-eared Owl playback and a scenario with no playback for comparison. Each row of the graph matrix represents the effect of the playback sequence listed on the far left. Each column of the matrix represents one of the focal species: Northern Saw-whet, Barred, and Great Horned Owl from left to right. Vertical black lines represent the point in time when a playback was broadcast, and the colored blocks denote the period of time where the cumulative detection probability was < 0.95. Colored blocks are absent when the period of time where the cumulative detection probability was < 0.95 required more than 13 minutes. Data were collected from survey routes distributed throughout Maine, USA, from 2004 – 2013, and analyzed using a multispecies occupancy analysis in Program MARK

TABLE A1. Beta estimates and associated standard error for each parameter of the leading models from the three sections of model selection.

Model[a]	Parameter[a]	Estimate	SE
Base	p: Intercept/NSWO 2013	-0.7685	0.1233
	p: BADO 2004	-0.6558	0.1350
	p: GHOW 2004	-0.3681	0.1512
	p: NSWO 2004	-0.0999	0.1464
	p: BADO 2005	-0.6091	0.1366
	p: GHOW 2005	-0.5135	0.1706
	p: NSWO 2005	0.0532	0.1336
	p: BADO 2006	-0.4648	0.1343
	p: GHOW 2006	0.1726	0.1512
	p: NSWO 2006	-0.3399	0.1362
	p: BADO 2007	-0.4030	0.1318
	p: GHOW 2007	0.0608	0.1434
	p: NSWO 2007	0.1474	0.1392
	p: BADO 2008	-0.6367	0.1382
	p: GHOW 2008	-0.5664	0.1641
	p: NSWO 2008	-0.8967	0.2569
	p: BADO 2009	-0.6715	0.1448
	p: GHOW 2009	-0.6887	0.1811
	p: NSWO 2009	-0.2116	0.1777
	p: BADO 2010	-0.3402	0.1397
	p: GHOW 2010	-0.2349	0.1905
	p: NSWO 2010	-0.0684	0.1671
	p: BADO 2011	-0.2746	0.1360
	p: GHOW 2011	-0.0324	0.1635
	p: NSWO 2011	-0.2855	0.1628
	p: BADO 2012	-0.4516	0.1367
	p: GHOW 2012	-0.0783	0.1728
	p: NSWO 2012	-0.0467	0.1572
	p: BADO 2013	-0.5529	0.1460
	p: GHOW 2013	-0.4551	0.1850
	p: BADO+OD	0.0673	0.0382
	p: BADO+OD2	-0.0456	0.0114
	p: GHOW+OD	-0.2177	0.0735
	p: GHOW+OD2	-0.1095	0.0336
	p: NSWO+OD	-0.0476	0.0532
	p: NSWO+OD2	-0.0577	0.0173

Base + P + TM + CC + T + N + W	p: Intercept/NSWO 2013	-0.7433	0.1278
	p: BADO 2004	-0.6842	0.1393
	p: GHOW 2004	-0.4087	0.1560
	p: NSWO 2004	-0.1997	0.1520
	p: BADO 2005	-0.6086	0.1409
	p: GHOW 2005	-0.5290	0.1764
	p: NSWO 2005	0.0794	0.1398
	p: BADO 2006	-0.5248	0.1387
	p: GHOW 2006	0.0956	0.1560
	p: NSWO 2006	-0.4436	0.1417
	p: BADO 2007	-0.4119	0.1362
	p: GHOW 2007	-0.0235	0.1496
	p: NSWO 2007	0.0277	0.1459
	p: BADO 2008	-0.6591	0.1425
	p: GHOW 2008	-0.5810	0.1684
	p: NSWO 2008	-0.9358	0.2609
	p: BADO 2009	-0.7047	0.1491
	p: GHOW 2009	-0.6425	0.1868
	p: NSWO 2009	-0.1262	0.1822
	p: BADO 2010	-0.3768	0.1448
	p: GHOW 2010	-0.1947	0.2018
	p: NSWO 2010	-0.1795	0.1725
	p: BADO 2011	-0.2735	0.1403
	p: GHOW 2011	-0.1068	0.1679
	p: NSWO 2011	-0.3312	0.1673
	p: BADO 2012	-0.5172	0.1416
	p: GHOW 2012	-0.1230	0.1790
	p: NSWO 2012	-0.1317	0.1627
	p: BADO 2013	-0.5676	0.1513
	p: GHOW 2013	-0.5451	0.1926
	p: BADO+OD	0.0653	0.0397
	p: BADO+OD2	-0.0447	0.0119
	p: GHOW+OD	-0.1309	0.0809
	p: GHOW+OD2	-0.1329	0.0343
	p: NSWO+OD	-0.0622	0.0556
	p: NSWO+OD2	-0.0516	0.0179
	p: BADO+P	-0.0428	0.0184
	p: GHOW+P	-0.0130	0.0480
	p: NSWO+P	-0.0912	0.0401
	p: BADO+TM	-0.0360	0.0202

	p: GHOW+TM	0.0917	0.0439
	p: NSWO+TM	-0.0566	0.0311
	p: BADO+CC	0.0454	0.0204
	p: GHOW+CC	-0.0520	0.0384
	p: NSWO+CC	0.0299	0.0328
	p: BADO+T	0.0445	0.0233
	p: GHOW+T	-0.1243	0.0523
	p: NSWO+T	0.0183	0.0300
	p: BADO+N	-0.0518	0.0190
	p: GHOW+N	-0.1381	0.0370
	p: NSWO+N	-0.1005	0.0276
	p: BADO+W	-0.0319	0.0193
	p: GHOW+W	-0.1420	0.0386
	p: NSWO+W	-0.1849	0.0350
Base + ALL-PB	p: Intercept/NSWO 2013	-0.9924	0.1410
	p: BADO 2004	-0.6321	0.1569
	p: GHOW 2004	-0.2309	0.1806
	p: NSWO 2004	-0.1516	0.1540
	p: BADO 2005	-0.5830	0.1584
	p: GHOW 2005	-0.3829	0.1978
	p: NSWO 2005	0.0135	0.1411
	p: BADO 2006	-0.4311	0.1563
	p: GHOW 2006	0.3463	0.1810
	p: NSWO 2006	-0.4075	0.1435
	p: BADO 2007	-0.3765	0.1538
	p: GHOW 2007	0.2405	0.1733
	p: NSWO 2007	0.1592	0.1447
	p: BADO 2008	-0.6223	0.1596
	p: GHOW 2008	-0.4214	0.1913
	p: NSWO 2008	-0.9399	0.2619
	p: BADO 2009	-0.6590	0.1656
	p: GHOW 2009	-0.5490	0.2065
	p: NSWO 2009	-0.2264	0.1839
	p: BADO 2010	-0.3095	0.1611
	p: GHOW 2010	-0.0745	0.2160
	p: NSWO 2010	-0.0734	0.1733
	p: BADO 2011	-0.2391	0.1578
	p: GHOW 2011	0.1403	0.1913
	p: NSWO 2011	-0.3049	0.1685
	p: BADO 2012	-0.4277	0.1583

p: GHOW 2012	0.0911	0.1998
p: NSWO 2012	-0.0501	0.1632
p: BADO 2013	-0.5346	0.1668
p: GHOW 2013	-0.3057	0.2103
p: BADO+OD	0.0705	0.0392
p: BADO+OD2	-0.0476	0.0116
p: GHOW+OD	-0.2269	0.0756
p: GHOW+OD2	-0.1114	0.0342
p: NSWO+OD	-0.0498	0.0550
p: NSWO+OD2	-0.0604	0.0177
p: Playback	-2.0315	0.0604
p: BADO - NSWOpb	-0.0046	0.0975
p: GHOW - NSWOpb	0.2992	0.1543
p: NSWO - NSWOpb	0.7933	0.1132
p: BADO - LEOWpb	0.0758	0.0749
p: GHOW - LEOWpb	0.1985	0.1299
p: NSWO - LEOWpb	0.5401	0.1188
p: BADO - BADOpb	0.7398	0.0488
p: GHOW - BADOpb	0.3921	0.0871
p: NSWO - BADOpb	0.6911	0.0751
p: BADO - GHOWpb	0.3270	0.0619
p: GHOW - GHOWpb	0.5075	0.1062
p: NSWO - GHOWpb	0.3703	0.0939

[a] “Base” represents the best model from our base model selection species-year interactive effect with an additive quadratic effect of ordinal date. Single/double letter codes represent covariates applied to the model: CC = cloud cover, L = latitude, N = noise, P = precipitation, TM = time of observation expressed in time since midnight, T = Temperature, and W = wind speed. The term “ALL-PB” represents that the model includes the effects of Barred, Great Horned, Long-eared, and Northern Saw-whet Owl playback. “p:” is used to present that the beta value is a detection probability. “Playback” represents the effect of detection during the sampling intervals during which a playback was broadcast. BADO, GHOW, LEOW, and NSWO are banding codes for Barred, Great Horned, Long-eared, and Northern Saw-whet Owls respectively. The term “pb” represents the effect of a playback of the species denoted by the four letter code that precedes it.

TABLE A2. p^* values for Northern Saw-whet, Barred, and Great Horned Owl during each sampling interval of each survey structure that we tested.

Survey Structure[a]	Sampling Interval[a]	Interval Type	Interval Duration (sec)	NSWO p^*	BADO p^*	GHOW p^*
Saw-whet + Barred + Great Horned	1	Listening	60	0.2416	0.1941	0.2739
	2	Listening	60	0.4248	0.3505	0.4598
	3	Listening	60	0.5638	0.4766	0.5981
	4	Saw-whet	20	0.6006	0.4904	0.6180
	5	Listening	40	0.7657	0.5774	0.7265
	6	Listening	60	0.8625	0.6496	0.8042
	7	Barred	20	0.8731	0.6693	0.8185
	8	Listening	40	0.9224	0.7728	0.8866
	9	Listening	60	0.9526	0.8438	0.9292
	10	Listening	60	0.9710	0.8927	0.9558
	11	Listening	60	0.9823	0.9262	0.9724
	12	Listening	60	0.9892	0.9493	0.9827
	13	Listening	60	0.9934	0.9652	0.9892
	14	Great Horned	20	0.9937	0.9666	0.9900
	15	Listening	40	0.9956	0.9750	0.9936
	16	Listening	60	0.9969	0.9812	0.9959
Long-eared + Barred + Great Horned	1	Listening	60	0.2416	0.1941	0.2560
	2	Listening	60	0.4248	0.3505	0.4465
	3	Listening	60	0.5638	0.4766	0.5882
	4	Long-eared	20	0.5910	0.4939	0.6097
	5	Listening	40	0.7286	0.5986	0.7250
	6	Listening	60	0.8200	0.6816	0.8063
	7	Barred	20	0.8338	0.6995	0.8205
	8	Listening	40	0.8984	0.7935	0.8879
	9	Listening	60	0.9379	0.8581	0.9300
	10	Listening	60	0.9620	0.9025	0.9563
	11	Listening	60	0.9768	0.9330	0.9727
	12	Listening	60	0.9858	0.9539	0.9829
	13	Listening	60	0.9913	0.9683	0.9893
	14	Great Horned	20	0.9918	0.9697	0.9901
	15	Listening	40	0.9942	0.9773	0.9937
	16	Listening	60	0.9960	0.9830	0.9960
Saw-whet + Barred	1	Listening	60	0.2416	0.1941	0.2560
	2	Listening	60	0.4248	0.3505	0.4465

	3	Listening	60	0.5638	0.4766	0.5882
	4	Saw-whet	20	0.6006	0.4904	0.6085
	5	Listening	40	0.7657	0.5774	0.7198
	6	Listening	60	0.8625	0.6496	0.7994
	7	Barred	20	0.8731	0.6693	0.8140
	8	Listening	40	0.9224	0.7728	0.8838
	9	Listening	60	0.9526	0.8438	0.9275
	10	Listening	60	0.9710	0.8927	0.9547
	11	Listening	60	0.9823	0.9262	0.9717
	12	Listening	60	0.9892	0.9493	0.9823
	13	Listening	60	0.9934	0.9652	0.9890
	14	Listening	60	0.9959	0.9761	0.9931
	15	Listening	60	0.9975	0.9835	0.9957
	16	Listening	60	0.9985	0.9887	0.9973
Long-eared + Barred	1	Listening	60	0.2416	0.1941	0.2560
	2	Listening	60	0.4248	0.3505	0.4465
	3	Listening	60	0.5638	0.4766	0.5882
	4	Long-eared	20	0.5910	0.4939	0.6097
	5	Listening	40	0.7286	0.5986	0.7250
	6	Listening	60	0.8200	0.6816	0.8063
	7	Barred	20	0.8338	0.6995	0.8205
	8	Listening	40	0.8984	0.7935	0.8879
	9	Listening	60	0.9379	0.8581	0.9300
	10	Listening	60	0.9620	0.9025	0.9563
	11	Listening	60	0.9768	0.9330	0.9727
	12	Listening	60	0.9858	0.9539	0.9829
	13	Listening	60	0.9913	0.9683	0.9893
	14	Listening	60	0.9947	0.9782	0.9933
	15	Listening	60	0.9968	0.9851	0.9958
	16	Listening	60	0.9980	0.9897	0.9974
Saw-whet	1	Listening	60	0.2416	0.1941	0.2560
	2	Listening	60	0.4248	0.3505	0.4465
	3	Listening	60	0.5638	0.4766	0.5882
	4	Saw-whet	20	0.6006	0.4904	0.6085
	5	Listening	40	0.7657	0.5774	0.7198
	6	Listening	60	0.8625	0.6496	0.7994
	7	Listening	60	0.9193	0.7094	0.8564
	8	Listening	60	0.9527	0.7591	0.8972
	9	Listening	60	0.9722	0.8002	0.9264
	10	Listening	60	0.9837	0.8343	0.9473

	11	Listening	60	0.9904	0.8626	0.9623
	12	Listening	60	0.9944	0.8861	0.9730
	13	Listening	60	0.9967	0.9056	0.9807
	14	Listening	60	0.9981	0.9217	0.9862
	15	Listening	60	0.9989	0.9351	0.9901
	16	Listening	60	0.9993	0.9462	0.9929
Long-eared	1	Listening	60	0.2416	0.1941	0.2560
	2	Listening	60	0.4248	0.3505	0.4465
	3	Listening	60	0.5638	0.4766	0.5882
	4	Long-eared	20	0.5910	0.4939	0.6097
	5	Listening	40	0.7286	0.5986	0.7250
	6	Listening	60	0.8200	0.6816	0.8063
	7	Listening	60	0.8806	0.7474	0.8636
	8	Listening	60	0.9208	0.7997	0.9039
	9	Listening	60	0.9474	0.8411	0.9323
	10	Listening	60	0.9651	0.8740	0.9523
	11	Listening	60	0.9769	0.9000	0.9664
	12	Listening	60	0.9846	0.9207	0.9763
	13	Listening	60	0.9898	0.9371	0.9833
	14	Listening	60	0.9932	0.9501	0.9883
	15	Listening	60	0.9955	0.9604	0.9917
	16	Listening	60	0.9970	0.9686	0.9942

[a] MOMP stands for the Maine Owl Monitoring Program. BADO, GHOW, LEOW, and NSWO are banding codes for Barred, Great Horned, Long-eared, and Northern Saw-whet Owls respectively. The term "pb" represents the effect of a playback of the species denoted by the four letter code that precedes it.

AUTHOR'S BIBLIOGRAPHY

Kyle Lima (a.k.a., that kid who's obsessed with birds), was hatched in a nest wedged between two crooked branches in a semi-deciduous Brazilian woodland bordered by tall caatinga to a pair of *Picumnus limae* parents (hence where he got his last name, now anglicized). Growing up with birds as parents provided him with an amazing childhood, and allowed him to be able to communicate with many forms of wildlife. At the age of nine, Kyle left his parents to join a group of nomadic scientists, where he acted as a guide and human-wildlife translator. He spent the next nine years communicating with wildlife all over the world, learning 17 languages, and guiding these nomads through tropical high elevation rainforest, permafrost alpine tundra, thorny shrub savanna, rocky seasonal deserts, and across a literal continent of ice.

Kyle did not attend high school, but rather got his basic education through homeschooling lessons provided by the nomadic scientists in exchange for his guiding services. Due to his guiding expertise and his ability to talk to wildlife, the United States awarded him full citizenship at the age of 18, just 'cause. Kyle soon started his education at the University of Maine where he majored in Wildlife Ecology, with a triple concentration in bird things, concentration, and Conservation Biology. He is very active at the University, participating extensively in various clubs and organizations such as the Wildlife Sociology, Ponderers United, Climbing Random Things that Shouldn't be Climbed Association, and founding the All Birds Are Just Chickens Club. Kyle also likes to give back to his community by staring at peoples' bird feeders through binoculars, and speaking about conservation and ecology to local Hannaford shoppers who are often too bewildered to respond.

During college he realized that he needed money (stupid society!), so he found work as a Spruce Grouse wrangler and professional plant counter in temperate boreal forests, a passionate organism identifier in coastal montane woodlands, and a rotting chicken neck distributor to scavengers in shrub encroached savannas. After graduation, Kyle plans to disappear into nature to build a sustainable treehouse homestead, look at birds, and learn from indigenous peoples before returning to the developed world to obtain his M.S.